The Multiband Photometry of GRB Host Galaxies: Comparison with the Spectral Energy Distributions of Nearby Galaxies and Theoretical Modeling

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Abstract. We present one of the results of $BVRI$ photometry of the hosts of GRB for the host galaxy of GRB 970508 and the theoretical modeling of its continuum spectral energy distribution (SED) to show that it is important to take into account internal extinction in the host galaxies. We compared the $BVRI$ broad-band flux spectrum of the host to template SEDs of local starburst galaxies and found that there is a significant internal extintion in this host. Moreover, this comparison allows us to derive the absolute magnitude ($M_{B_{rest}}$) and rouhgly estimate reddening (A_V). Population synthesis modeling of the continuum SED for different reddening laws ([4] and [5]) demostrates that the observational data of the host galaxy of GRB 970508 are best fitted by the spectral properties of a model SED with extinction of $A_V \approx 2$.

The multiband observations of GRB host galaxies were performed with the 6-m telescope of SAO RAS in 1998–2000. In details the data reduction and photometry of the host galaxies are described in [12]. As *a first approximation* for an estimate of internal extinction, we compared our broad-band flux spectrum of the host galaxy of GRB 970508 (as an example) to SEDs of local starburst galaxies. We used S1, S2, S3, S4, S5, S6 averaged template SEDs for the local starburst galaxies from [3]. The spectra of local starburst were grouped according to increasing values of the color excess $E(B-V)$. Fig. 1 demonstrates the best fitting (minimum of $\chi^2/d.o.f$) of our broad-band flux spectrum by the starburst template galaxies (in Fig. 1 and 2 FWHM of each band is shown, taking into account z, by dashed horizontal lines with bars). Using $E(B-V)$ for the S5 template and reddening laws from [5] and [4] we can estimate the value of A_V, which is in ranges $A_V = 1.58 \div 1.86$ and $A_V = 2.07 \div 2.43$, respectively. The same comparisons of the $BVRI$ broad-band spectra with the local template SEDs allows us to derive K-correction and absolute magnitudes.In Table 1 we present the observed R-band magnitudes and the estimates of $M_{B_{rest}}$ derived by us [12] and other authors for eight GRB host galaxies.

As *a second approximation* for the estimate of internal extinction, we constructed a set of model theoretical templates for the host galaxy of GRB 970508 using population synthesis modeling. We used the PEGASE package ([7]) and

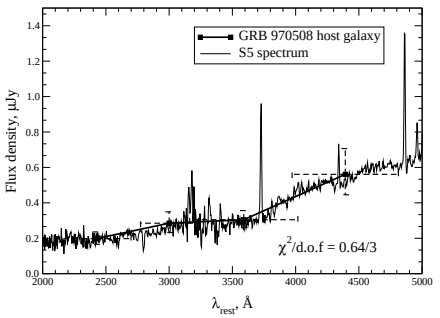

Fig. 1. A comparison of the GRB 970508 host galaxy broad-band rest-frame ($z = 0.835$) flux spectrum with the SED of S5 template galaxies (see [6]). Fluxes of S5 template were scaled for the best fitting.

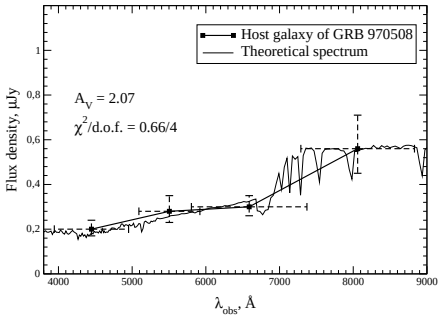

Fig. 2. The best fit for the model SED to the $BVRI$ photometry of the host galaxy GRB 970508, assuming the extinction law from [4]. Wavelengths are in the observed frame.

Table 1. Observed and absolute magnitudes of GRB host galaxies

Host	observed magn. R	absolute magn. $M_{B_{rest}}$	reference
GRB 970228	24.6±0.2	-18.6	R: [8], $M_{B_{rest}}$: [2]
GRB 970508	24.99±0.17	-18.6	[12]
GRB 991208	24.36±0.15	-18.8	[12]
GRB 990712	21.80±0.06	-19.9	[9]
GRB 980613	23.58±0.1	-20.8	[12]
GRB 990123	24.47±0.14	-20.9	[12]
GRB 971214	25.69±0.3	-21.1	R: [12], $M_{B_{rest}}$: [10]
GRB 980703	22.30±0.08	-21.3	[12]

the following assumptions: the Sun metalicity, instantaneous burst of star formation, Salpeter initial mass function with the low and high mass cut-offs to be $0.1\,M_\odot\,yr^{-1}$ and $120\,M_\odot\,yr^{-1}$, respectively; cosmology with H_0=60 km s^{-1} Mpc^{-1}, Ω_M=0.3 and Ω_Λ=0.7. For the calculations of the resulting SED we applied a two-component model: the first component is just a burst ("burst" component) of star formation and the second one is an old ("old" component) stellar population. Both give corresponding contributions into the resulting continuous SED. The "burst" component is responsible for emission lines and nebular continuum. For this reasons, we roughly fixed the "burst" component parameters using the luminosity of the forbidden emission line [O II] by fitting to its observed flux from [1] and taking into account the assumed reddening laws. With the constructed set of the theoretical templates we found the minimum of $\chi^2/d.o.f$ for the $BVRI$ broad-band flux spectrum of the GRB host in two ranges of A_V obtained from the comparison with local starburst templates in *a first approximation*: $A_V = 2.07 \div 2.43$ and $A_V = 1.58 \div 1.86$ for two reddening laws [4] and

Table 2. The best fit model parameters

reddening curve	A_V	$\chi^2/d.o.f.$
Cardelli et al, [5]	1.6	1.03/4
Calzetti et al, [4]	2.07	0.66/4

[5]. According to our method, we derived the best fit parameters of the model SEDs which are given in Table 2. In Fig. 2 we plot the model SED in the case of the reddening curve from [4]. As it can be seen, the $BVRI$ broad-band flux spectrum of the host galaxy of GRB 970508 is best fitted by the theoretical template with sufficiently high internal extinction. We notice that the best fit parameters correspond to the A_V, which indeed, lies within the range of A_V derived from the comparison with the S5 template SED. Taking into account the reddening curve from [4], A_V from Table 2 and the lower limit of SFR from [1], we can estimate the extinction-corrected SFR (star formation rate) as follows: $\mathrm{SFR}_{corr} \approx 17\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$.

We emphasize that only the simplest model assumptions were made and we did not include in the modeling other possibilities (e.g. exponentially decreasing star formation scenario, subsolar metallicity). For comparison of our value of A_V, we draw attention that in the case of the host galaxy of GRB 990712 the extinction was obtained to be $A_V = 3.4^{+2.4}_{-1.7}$ for the extinction law from [5] (see [13]), which is about 2 times higher than our one ($A_V = 1.6$ for the same law). It should be noted in conclusion that the comparison of $BVRI$ broad-band flux spectrum of the host galaxy of GRB 970508 with local starburst templates and theoretical templates shows that it is likely to be of great importance to take into account internal extinction in GRB host galaxies.

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